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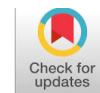
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Scratch-Assisted Joyful Learning to Improve Seventh-Grade Students' Mathematical Conceptual Understanding of Social Arithmetic

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ABSTRACT

Conceptual understanding of mathematics is a fundamental skill in mathematics learning. However, students often experience difficulties in connecting mathematical concepts with contextual problems in social arithmetic. This study aims to analyze the differences in students' mathematical conceptual understanding before and after the implementation of Scratch-assisted Joyful Learning on social arithmetic material. This study used a quantitative approach with a pre-experimental one-group pretest-posttest design. The population consisted of 189 7th-grade students of SMP Negeri L Sidoharjo in the 2025/2026 academic year. The sample was selected using cluster random sampling, resulting in Class VII.4 consisting of 28 students. Data were collected through conceptual understanding test questions, including indicators of restating concepts, classifying objects according to their properties, presenting concepts in various representations, choosing appropriate procedures or operations, and applying concepts to problem-solving situations. The instrument showed a validity coefficient ranging from 0.848 to 0.978 and a reliability coefficient of 0.970. The mean score increased from 48.00 (SD = 13.63) in the pretest to 92.00 (SD = 5.87) in the posttest, with a mean difference of 44.00 points. A one-tailed t-test showed that the calculated ttest (19.86) was greater than ttable (1.703), indicating a significant improvement in students' conceptual understanding of mathematics. These findings can be the basis for developing more adaptive and interactive learning interventions through the integration of Joyful Learning and Scratch in various mathematics learning contexts.



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Introduction

Mathematical conceptual understanding is an essential ability in mathematics learning because it enables students to understand the meaning, characteristics, and relationships of

mathematical concepts and to use them appropriately in different situations. [Kilpatrick et al., \(2002\)](#) explain that conceptual understanding involves comprehension of mathematical concepts, operations, and relationships among mathematical ideas. This understanding enables students to connect mathematical ideas rather than rely only on memorizing formulas. [Hasibuan et al., \(2023\)](#) further describe mathematical conceptual understanding through several abilities, including restating concepts, providing examples and non-examples, classifying objects according to their characteristics, and representing concepts in various mathematical forms. Students also need to use appropriate concepts and procedures when solving mathematical problems. Therefore, conceptual understanding involves the ability to interpret, represent, and apply mathematical concepts in mathematical and contextual situations.

Low mathematical conceptual understanding is associated with difficulties in interpreting mathematical information, connecting mathematical ideas, selecting appropriate procedures, and applying concepts when problem situations differ from previously learned examples. This condition was identified through preliminary observations and an interview with a mathematics teacher at SMP Negeri L Sidoharjo conducted on October 2, 2025. The seventh-grade students generally could solve problems similar to the examples provided by the teacher, but some students experienced difficulties when the problems were modified or presented in real-life situations. Students also had difficulties explaining concepts in their own words, connecting mathematical concepts, and applying concepts to problem-solving situations. These findings indicate that some students still relied on memorizing formulas rather than understanding the meaning and relationships underlying the concepts being learned.

One topic that requires adequate conceptual understanding is social arithmetic. Social arithmetic is closely related to everyday economic activities and includes concepts such as profit, loss, discounts, and gross, net, and tare relationships. However, the present study focuses specifically on profit, profit percentage, loss, and loss percentage. Understanding these concepts requires students to identify the relationships among purchase price, selling price, profit or loss, and percentage. Students may experience difficulties because solving social arithmetic problems requires more than recalling formulas. They need to interpret information presented in word problems, identify relevant quantities, understand percentage relationships, perform numerical operations, and select appropriate procedures. Therefore, although social arithmetic is contextual and familiar to students, its connection with everyday situations does not automatically ensure conceptual understanding. Students still need learning activities that help them connect contextual situations with mathematical concepts, representations, and procedures.

Learning that connects mathematical concepts with students' experiences and real-life contexts can support the development of meaningful conceptual understanding. [Agusdianita et al., \(2021\)](#) explain that learning connected to students' life contexts can facilitate students' understanding of mathematical concepts. [Sukestiyarno et al. \(2023\)](#) also emphasize that students' experiences and environments can support the construction of mathematical concepts. Similarly, [Purwasi et al. \(2026\)](#) report that mathematics learning connected with students' daily activities and real-life experiences can support more meaningful learning. These findings indicate that contextual learning can provide opportunities for students to interpret mathematical situations and connect them with the concepts being studied. However, contextual situations need to be accompanied by active learning activities that allow students to discuss, represent, and apply the concepts.

One instructional approach that can support active participation in mathematics learning is Joyful Learning. Joyful Learning is not limited to creating an enjoyable classroom atmosphere but involves learning activities that encourage students to participate, interact, communicate, and reflect during the learning process. [Haryanti \(2021\)](#) found that the

implementation of Joyful Learning could increase students' involvement in mathematics learning. Nabila et al., (2025) also reported that Joyful Learning is associated with students' motivation and mathematics learning achievement. These characteristics make Joyful Learning relevant to mathematics learning that requires students to express their understanding, discuss mathematical ideas, solve problems collaboratively, and communicate their reasoning.

The implementation of Joyful Learning can be supported by interactive digital learning media. Purwasi et al. (2024) explain that digital technology can support the development of learning activities and 21st-century skills. One digital medium that can be used in mathematics learning is Scratch. Scratch is a visual programming platform that allows learning activities to be presented through animations, simulations, and interactive games. Candra & Mahpudin, (2024) found that Scratch-based learning media could improve students' mathematical abilities. Rahadi & Ismiyati, (2024) reported that Scratch-based mathematics learning media were appropriate for learning and could increase student engagement. Juniar et al., (2024) also showed that Scratch-based educational games could provide interactive mathematics learning experiences.

In the present study, Scratch was developed and used as an educational game to support the implementation of Joyful Learning in social arithmetic. The game contained learning materials, instructions, practice exercises, and evaluative activities related to profit, profit percentage, loss, and loss percentage. The practice activities were integrated with worksheet. Students observed the materials and instructions presented through Scratch, discussed the questions with their group members, and recorded their solutions on the. Thus, Scratch was not used merely as a presentation medium but was integrated into the learning activities. During the experiencing stage, students studied contextual social arithmetic materials presented through the game. During the interacting stage, students discussed the materials and solved problems collaboratively. During the communicating stage, students presented their solutions and reasoning, while the teacher provided feedback and clarified misconceptions. During the reflecting stage, students and the teacher reviewed the concepts and learning experiences. The implementation of these activities is consistent with the learning process described in the study, in which students used Scratch to study profit and loss materials, discuss problems, complete worksheet activities, communicate their solutions, and reflect on their understanding.

The previous studies provide evidence regarding the potential of Scratch and Joyful Learning in mathematics learning. Candra & Mahpudin, (2024) focused on the use of Scratch to support students' mathematical abilities, while Rahadi & Ismiyati, (2024) examined Scratch-based mathematics learning media and student engagement. Juniar et al., (2024) developed Scratch-based educational games for mathematics learning. Meanwhile, Haryanti, (2021) and Nabila et al. (2025) examined the implementation and characteristics of Joyful Learning in mathematics education. Based on these studies, Scratch and Joyful Learning have been investigated as learning media or instructional approaches. However, the integration of Joyful Learning with a Scratch educational game to support students' mathematical conceptual understanding in social arithmetic has received less attention in the studies considered in this research. This provides a research gap for examining the combination of an instructional approach and interactive digital media within the same learning process.

The novelty of the present study lies in the integration of Joyful Learning, a Scratch-based educational game, and worksheet to support students' mathematical conceptual understanding of social arithmetic. The integration is designed to provide students with opportunities to experience contextual situations, interact with peers, communicate mathematical reasoning, and reflect on the concepts they have learned. This combination is particularly relevant to profit, profit percentage, loss, and loss percentage because these concepts require students to interpret

buying and selling situations, identify relationships among quantities, represent mathematical information, and select appropriate procedures. Therefore, the use of Scratch is positioned as part of the learning process rather than as a separate technological component. Based on the identified problems and research gap, this study aimed to determine students' mathematical conceptual understanding after the implementation of Joyful Learning assisted by a Scratch educational game on social arithmetic material. The study contributes empirical evidence on the integration of an active learning approach, interactive digital media, and worksheet to support conceptual understanding in junior high school mathematics learning. Therefore, the findings are limited to the characteristics of the selected students, school context, learning topic, intervention, and research design and should not be generalized to other populations or mathematical topics without further investigation.

Method

Types of research

This study employed a quantitative approach using a *pre-experimental design* in the form of a *one group pretest-posttest design*. The design consisted of one research group that received a pretest before the treatment and a posttest after the treatment. The treatment involved the implementation of Joyful Learning assisted by a Scratch-based educational game to support students' mathematical conceptual understanding (Sugiyono, 2021). The research design can be seen in Figure 1.

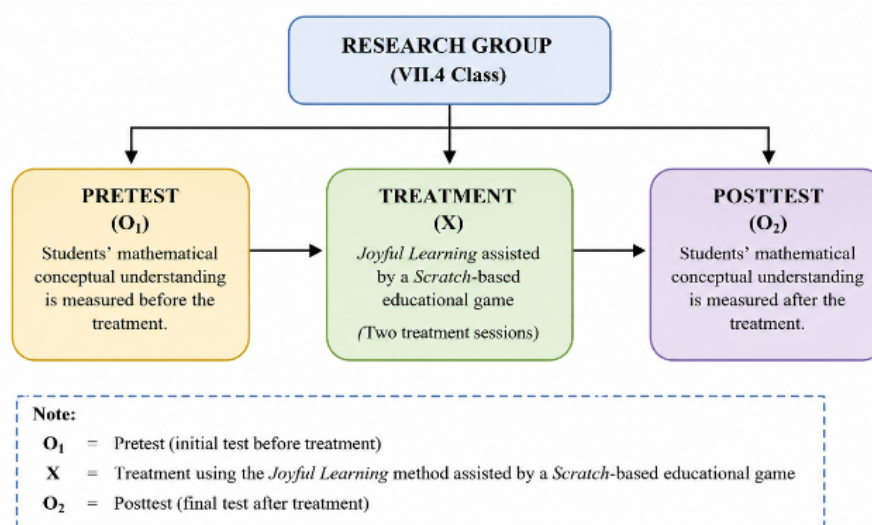


Figure 1. Research Design

Based on Figure 1, this design is used to examine the impact of treatment on students' conceptual understanding of mathematics by comparing their performance before and after the intervention, which is measured through pretest (O₁) and posttest (O₂) scores.

Population and Sample

The population of this study consisted of all seventh-grade students of SMP Negeri L Sidoharjo in the 2025/2026 academic year, comprising six classes with a total of 189 students. The research sample was selected using **cluster random sampling**, in which one intact class

was randomly selected from the six seventh-grade classes. In [Table 1](#) it can be seen that the selected research sample was Class VII.4, which consisted of 28 students.

Table 1. Demographic Characteristics of the Research Participants

Gender	Frequency (n)	Percentage (%)
Male	14	50.0
Female	14	50.0
Total	28	100.00

Source: School administrative data, 2025/2026 academic year

Based on [Table 1](#), it shows that the research participants consisted of 28 seventh-grade students from Class VII.4. The sample consisted of 14 male students (50.0%) and 14 female students (50.0%). Thus, the participants had a balanced gender distribution.

Research Procedure

The research was conducted in four meetings, consisting of one pretest session, two treatment sessions, and one posttest session. The treatment sessions implemented Joyful Learning assisted by a Scratch-based educational game on social arithmetic material. The learning activities focused on profit, profit percentage, loss, and loss percentage.

Pretest

Before the treatment, students were administered a mathematical conceptual understanding pretest to determine their initial understanding of social arithmetic concepts. The pretest consisted of essay questions covering the indicators of mathematical conceptual understanding used in this study. Students completed the test individually under the supervision of the researcher and mathematics teacher. In the first treatment session, students learned about profit and profit percentage using the Scratch-based educational game. Scratch functioned as an interactive educational game containing learning materials, contextual examples, instructions, practice exercises, and evaluative activities. During the experiencing stage, students observed and studied the learning materials presented through Scratch. During the interacting stage, students discussed the material and solved contextual problems collaboratively with their group members. During the communicating stage, students presented their solutions and explained their reasoning, while the teacher provided feedback and clarified misconceptions. During the reflecting stage, the teacher and students reviewed the material and discussed students' understanding and difficulties.

The practice exercises presented through the Scratch game were integrated with worksheet. Students did not enter their complete solutions directly into the Scratch game. Instead, Scratch was used to present the questions and instructions, while students discussed the problems with their group members and recorded their solutions on the worksheet. In the second treatment session, students learned about loss and loss percentage using the same Joyful Learning stages assisted by the Scratch educational game. During the experiencing stage, students studied explanations, formulas, and contextual examples of loss presented through Scratch. During the interacting stage, students discussed the material and solved problems collaboratively. During the communicating stage, students presented their solutions and received feedback from the teacher. During the reflecting stage, the teacher and students reviewed the concepts and discussed the students' learning experiences.

The practice activities on loss and loss percentage were also integrated with worksheet. Students followed the questions and instructions presented through Scratch, discussed the solutions with their group members, and recorded the results of their discussions on the worksheet. After the two treatment sessions were completed, students were administered a mathematical conceptual understanding posttest. The posttest used essay questions based on the same conceptual understanding indicators as the pretest. The posttest was administered individually to measure students' mathematical conceptual understanding after participating in the learning activities. The posttest was conducted under the supervision of the researcher and mathematics teacher.

Teacher's Role

During the treatment, the teacher acted as a facilitator and learning guide. The teacher provided instructions for the learning activities, guided students in using the Scratch educational game, facilitated group discussions, monitored students' activities, provided feedback, clarified misconceptions, and guided students during the reflection stage.

Test Supervision

During the pretest and posttest, students completed the test individually. The researcher and mathematics teacher supervised the test administration to ensure that students followed the instructions and completed the test independently.

Instruments

The research instrument used in this study was a mathematical conceptual understanding test in the form of essay questions on social arithmetic material. The instrument was developed based on indicators of mathematical conceptual understanding adapted from Kilpatrick et al., (2002) and Rahayu & Pujiastuti (2023), which include the ability to restate a concept, provide examples and non-examples of a concept, classify objects according to their properties based on the concept, represent concepts in various mathematical representations, and apply concepts to solve problems. The scope of learning outcomes, learning objectives, and indicators of conceptual understanding are presented in Table 2.

Table 2. Mathematical Concept Understanding Test Grid

Learning Outcomes	Learning objectives	Concept Understanding Indicator
At the end of Phase D, students are expected to be able to use relationships among numbers and arithmetic operations to solve problems in various real-life contexts. Students are also expected to apply social arithmetic concepts, particularly profit, profit percentage, loss, and loss percentage, to solve contextual problems and interpret the results obtained according to the given situations.	Students are able to determine profit, profit percentage, loss, and loss percentage based on the given information and use these concepts to solve problems related to simple economic activities in everyday life.	1. Restate a concept. 2. Provide examples and non-examples of a concept. 3. Classify objects according to their properties based on the concept. 4. Represent concepts in various forms of mathematical representation. 5. Use and select appropriate procedures or operations to solve problems.

Furthermore, the blueprint of the mathematical conceptual understanding test can be seen in **Table 3**.

Table 3. Mapping of Conceptual Understanding Indicators to Test Items

Concept Understanding Indicator					Question Items
1	2	3	4	5	
√	√			√	Adit bought a toy for Rp30,000 and sold it again for Rp25,000. After that, he stated that he incurred a “LOSS”. a. Explain in your own words what is meant by a loss in a buying and selling transaction! b. Calculate the amount of loss incurred by Adit! c. Provide another example of a transaction that results in a loss.
√	√	√		√	Rani carried out the following transactions: She bought a mask for Rp3,000 and sold it for Rp3,000; then she bought a scarf for Rp20,000 and sold it for Rp25,000; finally, she bought a keychain for Rp5,000 and sold it for Rp4,000. a. Explain by classifying each of the three transactions as a profit, a loss, or neither profit nor loss! b. Calculate the amount of profit or loss obtained from each transaction.
√	√				Bella bought a jacket for Rp200,000 and sold it again for Rp250,000. a. Determine whether Bella made a profit or incurred a loss, then calculate the amount of profit or loss! b. Explain and calculate the percentage of profit earned by Bella based on the purchase price!
√				√	A merchant purchased a pair of shoes for Rp300,000. Due to low demand, the shoes were sold for Rp250,000. a. Explain why the merchant incurred a loss based on the comparison between the purchase price and the selling price! b. Present the steps for calculating the loss in a systematic manner!
			√	√	Observe Table 1, which contains transaction data recorded by Nadia.

Table 1. Transaction Results

Goods	Purchase price	Selling price
Hoodies	Rp150.000	Rp180.000
Shirt	Rp50.000	Rp50.000
Skirt	Rp80.000	Rp70.000

- Show the calculations used to determine the amount of profit or loss for each item.
- Calculate the percentage of profit or loss for each item.

Instrumen Validity Testing

Rahman & Nasryah (2019) explains that validity refers to the accuracy and appropriateness of an instrument in measuring the intended research objectives. To determine the validity of the test instrument, the Product Moment correlation formula was used as follows.

$$r_{xy} = \frac{n \sum XY - (\sum X)(\sum Y)}{\sqrt{[n \sum X^2 - (\sum X)^2][n \sum Y^2 - (\sum Y)^2]}} \quad (\text{Supardi, 2016})$$

Information:

r_{xy} : Correlation coefficient between variable X and variable Y

n	:	Many test takers
X	:	Assess the test results
Y	:	Total value

The interpretation of the Product Moment correlation coefficient values according to Melisari et al., (2020) can be clearly seen in Table 4.

Table 4. Correlation Coefficient Criteria

Correlation Coefficient	Criteria
$0,80 < r_{xy} \leq 1,00$	Very high
$0,60 < r_{xy} \leq 0,80$	High
$0,40 < r_{xy} \leq 0,60$	Enough
$0,20 < r_{xy} \leq 0,40$	Low
$0,00 < r_{xy} \leq 0,20$	Very Low

The value of r_{count} was compared with r_{table} . At a significance level of 5% or $\alpha = 0.05$, $dk = n - 2$ was used to determine the value of r_{table} . Therefore, a test item was considered valid if $r_{count} > r_{table}$. Conversely, a test item was considered invalid if $r \leq r_{table}$. The results of the item validity analysis can be seen in Table 5.

Table 5. Summary of Item Validity Test Results

Number Question	r_{count}	Category	r_{table}	Validity
1a	0,929	very high	0,388	Valid
1b	0,891	very high	0,388	Valid
1c	0,915	very high	0,388	Valid
2a	0,935	very high	0,388	Valid
2b	0,978	very high	0,388	Valid
3a	0,975	very high	0,388	Valid
3b	0,890	very high	0,388	Valid
4a	0,848	very high	0,388	Valid
4b	0,897	very high	0,388	Valid
5a	0,879	very high	0,388	Valid
5b	0,860	very high	0,388	Valid

Based on Table 5, the results of the validity analysis showed that the coefficient values (r_{count}) of all five test items were higher than the value of (r_{table}) which was 0.388. The obtained r_{count} values ranged from 0.848 to 0.978 indicating that all scoring components were valid and suitable for use as research instruments. In addition, the validity level of each test item was classified as very high, indicating that the instrument had good quality in measuring students' mathematical conceptual understanding.

Instrumen Reliability Testing

According to Busnawir (2023), reliability refers to the extent to which an instrument can be trusted based on its measurement results. Reliability is determined to assess whether a test instrument can produce consistent results. Similar results will be obtained if the test instrument has a high level of reliability; conversely, if the reliability level is low, the test items are considered unreliable. The formula used to calculate the reliability coefficient of the test items is as follows:

$$r_{11} = \left[\frac{k}{k-1} \right] \left[1 - \frac{\sum \sigma_b^2}{\sigma_i^2} \right] \quad (\text{Sugiyono, 2017})$$

Information:

r_{11}	:	Reliability coefficient
k	:	The number of questions
$\sum \sigma_b^2$	:	Variance of score of question i
σ_t^2	:	Total score variance

To classify the magnitude of the reliability coefficient value according to [Haq \(2022\)](#) can be seen in [Table 6](#).

Table 6. Instrument Reliability Correlation Coefficient Criteria

No	σ_b^2	σ_t^2	r_{11}	Criteria
1a	1,102			
1b	0,840			
1c	0,976			
2a	3,090			
2b	2,633			
3a	3,544	138,043	0,970	very high
3b	0,870			
4a	0,870			
4b	0,925			
5a	0,846			
5b	0,652			
Amount	16,35	138,04	0,970	

Based on [Table 6](#), the results of the instrument reliability analysis showed that the sum of item variances $\sum \sigma_b^2$ was 16.35, the total variance σ_t^2 was 138.04, and the reliability coefficient r_{11} was 0.970 which falls into the very high category. Therefore, the test instrument was considered highly reliable and suitable for use as a measurement instrument in this study.

Collection and Analysis

The results obtained from the mathematical conceptual understanding test were determined using the scoring rubric according to [Argawi & Pujiastuti \(2021\)](#) and [Lala & Yusnidar \(2022\)](#). The scoring rubric can be seen in [Table 7](#).

Table 7. Scoring Guidelines for Conceptual Understanding Ability

Concept Understanding Indicator	Criteria
Restating a concept in one's own words	Not doing or not giving an answer Unable to restate concept Restating the concept but with many errors Restating the concept fairly accurately but incompletely Restate the concept precisely and completely
Providing examples and non-examples of a concept	Not doing or not giving an answer Not able to provide examples and non-examples Gives examples/not examples but lots of mistakes Providing examples and non-examples is quite appropriate but not complete

Concept Understanding Indicator	Criteria
Classifying objects according to conceptual characteristics	Provide examples and non-examples appropriately and correctly
	Not doing or not giving an answer
	Unable to classify objects
	Classifying objects but lots of mistakes
	Classifying objects is quite accurate but not complete
Presenting concepts in various mathematical representations	Classify objects correctly according to the concept
	Not doing or not giving an answer
	Unable to present mathematical representation
	Presents a representation but has many errors
	Presents a fairly accurate but incomplete representation
Using concepts to solve math problems	Presenting mathematical representations accurately
	Not doing or not giving an answer
	Unable to use concepts in problem solving
	Using the concept but lots of mistakes
	Using the concept is quite appropriate but not complete
	Using concepts appropriately to solve problems

The data were analyzed after obtaining the results of students' responses to the mathematical conceptual understanding test instrument. The students' responses were then interpreted based on the criteria presented in [Table 8](#).

Table 8. Categories of Mathematical Conceptual Understanding Ability

Score	Criteria
85,00-100,00	Very good
70,00-84,99	Good
55,00-69,99	Enough
40,00-54,99	Low
0,00-39,99	Very Low

Sumber: (Argawi & Pujiastuti, 2021)

The data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to describe students' mathematical conceptual understanding based on the pretest and posttest scores. Inferential analysis consisted of a normality test and a paired-samples *t*-test at a significance level of 5%. The paired-samples *t*-test was used because the pretest and posttest scores were obtained from the same group of students.

Results

In the implementation of learning using the Joyful Learning approach, students utilized Scratch as a supporting medium for learning social arithmetic. The Scratch media was designed interactively and systematically, incorporating learning materials, practice exercises, and evaluative quizzes. The implementation of this media also encouraged students' active involvement in the learning process, enabling conceptual understanding to develop more optimally, as shown in [Figure 2](#).

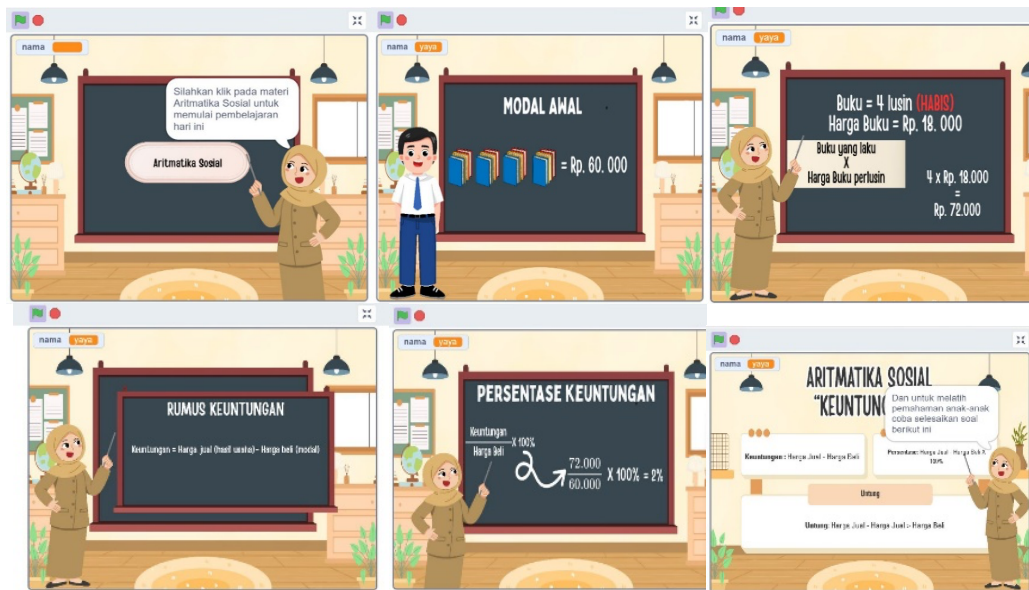


Figure 2. Display of the Profit Material

Figure 2 shows the display of the profit material in the Scratch educational game used during the first meeting. The material was presented in a concise, systematic, and interactive manner to help students understand the concept of profit in buying and selling activities. The presentation was complemented by illustrations, animations, and attractive visual displays, which enhanced students' attention and interest throughout the learning process. During the experiencing stage of Joyful Learning, students observed the material presented in the Scratch game individually and in groups. They read explanations about the definition of profit, the formula for calculating profit, and examples of its application in buying and selling activities commonly encountered in daily life. Through the interactive display, students were able to understand the concept of profit more easily because the material was presented visually and accompanied by contextual examples closely related to their experiences. Next, during the interacting stage, students discussed the material they had learned with their group members. In this activity, they exchanged ideas, asked questions, and provided responses regarding the concept of profit presented in the game. In addition, students collaborated to solve questions or challenges available in the Scratch game. These discussion activities encouraged active participation and helped students develop a deeper understanding of the concept of profit through knowledge sharing with their peers. After completing the discussion, students entered the communicating stage by presenting the results of their group discussions to the teacher and their classmates. They explained how they obtained their answers and the reasoning used to solve the given problems. At this stage, the teacher reinforced the concepts that had been learned and clarified any misconceptions that emerged during the discussion. In the *reflecting* stage, the teacher and students engaged in a question-and-answer session and summarized the profit material that had been studied. Students were given the opportunity to express what they had understood as well as any difficulties they still experienced during the learning process. Through reflection activities, students were able to strengthen their understanding of the concept of profit and relate it to real-life situations. Through the implementation of the Joyful Learning stages, namely experiencing, interacting, communicating, and reflecting, assisted by the Scratch educational game, students gained a more enjoyable, active, and meaningful learning experience. This condition helped students develop a deeper understanding of the concept of profit, enabling the learning objectives to be achieved effectively.



Figure 3. Scratch-Based Learning Material on Loss

Figure 3 shows the display of the loss material in the Scratch educational game used during the second meeting. The material was designed by relating the concept of loss to situations that are close to students' daily lives, making it easier for them to understand the concept being studied. The presentation was complemented by illustrations, animations, and engaging contextual examples, creating an enjoyable learning environment and increasing students' motivation to participate in the learning process. During the experiencing stage, students observed and studied the loss material presented through the Scratch game. They read explanations about the definition of loss, the formula for calculating loss, and examples of problems related to buying and selling activities in everyday life. Next, during the interacting stage, students discussed the material with their group members, exchanged ideas, asked questions, and collaborated in solving problems or challenges provided in the Scratch educational game. During the communicating stage, students presented the results of their group discussions regarding the solutions to problems related to loss, while the teacher provided feedback and reinforced the concepts that had been learned. Subsequently, during the reflecting stage, the teacher and students engaged in a question-and-answer session and summarized the loss material that had been studied, thereby strengthening students' understanding of the concept of loss. The loss material presented in the second meeting constituted the final treatment provided to the students before the administration of the posttest. After the entire learning process using the Joyful Learning method assisted by the Scratch educational game had been completed, the students took the posttest to measure their mathematical conceptual understanding of social arithmetic after receiving the treatment. Therefore, the posttest results were used to determine the effect of implementing the Joyful Learning method assisted by the Scratch educational game on students' mathematical conceptual understanding.

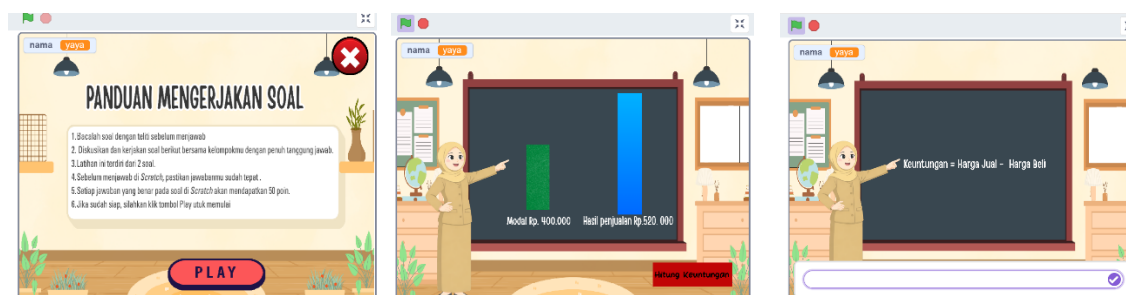




Figure 4. Scratch-Based Profit Practice Exercises

Figure 4 shows the display of profit and profit percentage practice exercises in the Scratch educational game. The exercises were completed collaboratively by students using worksheets integrated with the Scratch game. The questions and instructions were displayed through the game, while students wrote their answers on the provided worksheets. This activity was intended to help students understand the concepts of profit and profit percentage through group discussions and the application of these concepts in solving problems related to everyday life. In the learning process, the practice exercises presented in the Scratch educational game were not completed directly within the media. Instead, they were completed through worksheets integrated with the Scratch game. The game was used to present the learning materials, instructions, and questions, whereas the results of the discussions and students' answers were recorded on the worksheets completed collaboratively in groups. The Scratch media used in this study can be accessed through the following link: [mellisaagustriana | Linktree](https://mellisaagustriana.linktree). This media was developed by the researcher to support the implementation of Joyful Learning in teaching social arithmetic.



Figure 5. Display of Loss Practice Exercises

Figure 5 shows the display of loss and loss percentage practice exercises in the Scratch educational game. The exercises were completed collaboratively using worksheets integrated with the Scratch media. Students followed the instructions and questions presented in the game,

discussed the solutions with their group members, and recorded their answers on the worksheets. Through these activities, students were trained to understand the concepts of loss and loss percentage and to apply them in solving mathematical problems.

In the learning process, the practice exercises presented in the Scratch educational game were not completed directly within the media. Instead, they were completed through worksheets integrated with the Scratch game. The game was used to present the learning materials, instructions, and questions, while the results of group discussions and students' answers were recorded on the worksheets completed collaboratively. The Scratch media used in this study can be accessed through the following link: [mellisaagustriana | Linktree](#). This media was developed by the researcher to support the implementation of Joyful Learning in teaching social arithmetic.

The research data were obtained through a mathematical conceptual understanding test administered during the pretest and posttest. The results can be seen in Table 9.

Table 9. Descriptive Statistics of Pretest and Posttest Results

Statistics	Pretest	Posttest
Number of Students	28	28
Average value	48	92
The highest score	75	100
Lowest Value	32	79

Based on Table 9, the students' mean score increased from 48 on the pretest to 92 on the posttest. These results indicate that after the implementation of the Joyful Learning method assisted by the Scratch educational game, students' mathematical conceptual understanding improved.

Normality Test

Before conducting the paired-samples *t*-test, a normality test was performed on the difference scores between the posttest and pretest results. The difference score for each student was calculated by subtracting the pretest score from the posttest score. The normality test was conducted at a significance level of 5%.

Table 10. Results of the Normality Test of Difference Scores

Data	N	Shapiro-Wilk	Sig	Information
Difference scores	28	0,938	0,096	Normally distributed

Based on Table 10, the Shapiro-Wilk normality test showed that the difference scores between the posttest and pretest results were normally distributed. The significance value was 0.096, which was greater than 0.05. Therefore, the normality assumption was satisfied, and the data were appropriate for analysis using a paired-samples *t*-test.

Hypothesis Testing

The paired-samples *t*-test was conducted to determine whether there was a significant difference between students' mathematical conceptual understanding scores before and after the implementation of Joyful Learning assisted by the Scratch educational game.

- H_0 : There is no significant difference between students' mathematical conceptual understanding before and after the implementation of Joyful Learning assisted by the Scratch educational game.
- H_a : There is a significant difference between students' mathematical conceptual understanding before and after the implementation of Joyful Learning assisted by the Scratch educational game.

Table 11. Results of the Paired-Samples *t*-Test

t_{count}	t_{table}	df	α	Decision
19.20	1.703	27	0.05	H_0 rejected

Based on Table 11, the calculated *t* value was 19.20, while the critical *t* value was 1.703 with 27 degrees of freedom at a significance level of 5%. Since $t_{\text{count}} > t_{\text{table}}$ ($19.20 > 1.703$), H_0 was rejected and H_a was accepted. Therefore, there was a significant difference in students' mathematical conceptual understanding before and after the implementation of Joyful Learning assisted by the Scratch educational game.

Discussion

The results of the study showed an increase in students' mathematical conceptual understanding after the implementation of the Joyful Learning method assisted by the Scratch educational game. This increase was indicated by the students' average score, which increased from 48 on the pretest to 92 on the posttest. The results of the paired-samples *t*-test showed that the calculated *t* value was 19.20, which was greater than the critical *t* value of 1.703 at a significance level of 5%. Therefore, H_0 was rejected and H_a was accepted. These findings indicate that there was a significant difference in students' mathematical conceptual understanding before and after the implementation of Joyful Learning assisted by the Scratch educational game on social arithmetic material.

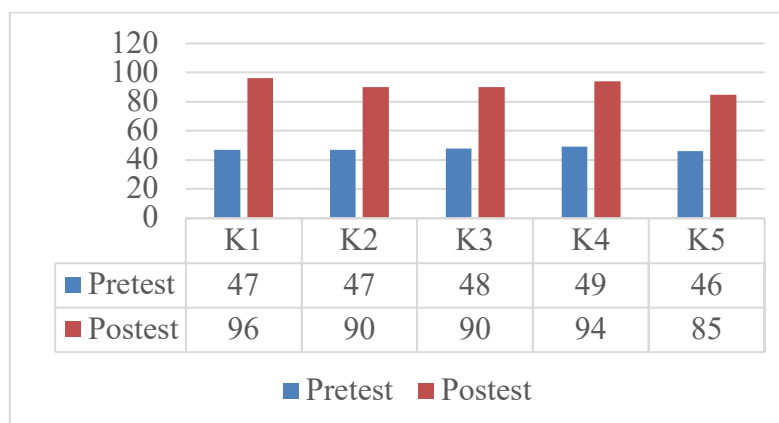


Figure 6. Graph of Students' Mathematical Conceptual Understanding by Indicator

Based on Figure 6, students' scores increased across all indicators of mathematical conceptual understanding after participating in the learning intervention. For the indicator of restating a concept (K1), the score increased from 47 on the pretest to 96 on the posttest. This increase indicates that students showed better performance in expressing mathematical concepts in their own words. For the indicator of providing examples and non-examples of a concept (K2), the score increased from 47 to 90. This result indicates that students showed better performance in distinguishing examples that meet the characteristics of a concept from those that do not. For the indicator of classifying objects according to conceptual properties (K3), the score increased from 48 to 90. This finding indicates that students showed better performance in classifying mathematical objects based on relevant characteristics. For the indicator of representing concepts in various mathematical representations (K4), the score increased from 49 to 94. This increase indicates that students showed better performance in expressing mathematical concepts through different forms of representation. For the indicator of using and selecting appropriate procedures in problem solving (K5), the score increased from

46 to 85. Overall, the increase across all five indicators indicates that students' performance in mathematical conceptual understanding was higher after participating in the learning intervention.

The increase in students' conceptual understanding can be discussed in relation to the learning activities implemented during the treatment. The Joyful Learning stages provided opportunities for students to experience mathematical situations, interact with group members, communicate their solutions, and reflect on the concepts they had learned. These activities were supported by the Scratch educational game, which presented contextual learning materials, examples, instructions, practice questions, and evaluative activities. Through the practice activities, students repeatedly worked with problems involving the relationships among purchase price, selling price, profit, loss, and their percentages. Students also discussed different solution strategies with their group members and recorded their solutions on the LKPD. These activities provided opportunities for students to connect contextual situations with mathematical concepts and procedures. During the communication stage, students presented their solutions and explained the reasoning used to obtain their answers, while the teacher provided feedback and clarified misconceptions. The reflection stage then provided an opportunity for students to review the concepts and procedures they had learned. Thus, the learning activities provided opportunities for students to develop conceptual understanding through contextual problems, repetition, discussion, feedback, and reflection.

The Scratch educational game functioned as an integral component of the Joyful Learning activities rather than as an independent treatment. The game presented learning materials, contextual examples, instructions, practice questions, and evaluative activities related to social arithmetic. The practice questions were integrated with worksheet, allowing students to discuss the questions presented through Scratch and record their solutions collaboratively. This activity enabled students to repeatedly apply the concepts of profit, profit percentage, loss, and loss percentage to contextual problems. The use of visual presentations and interactive activities also provided students with opportunities to examine mathematical information and connect it with the procedures used to solve the problems. Therefore, the findings of this study should be interpreted as the outcome of the integrated implementation of Joyful Learning assisted by Scratch, rather than as evidence of the separate contribution of Scratch alone.

The findings of the present study are in line with [Sumalia & Listiaji \(2024\)](#) and [Prasetya et al \(2020\)](#), who reported that Scratch could support mathematics learning and students' understanding of mathematical concepts. However, the present study differs in its integration of Scratch with the Joyful Learning stages and worksheet in learning social arithmetic. In the present study, the intervention focused on profit, profit percentage, loss, and loss percentage and measured mathematical conceptual understanding through five indicators. The students' mean score increased from 48 to 92 after the intervention. Thus, the present findings provide additional evidence concerning the use of Scratch as part of an integrated learning process for developing mathematical conceptual understanding in social arithmetic.

[Nabila et al., \(2025\)](#) reported that Scratch-based learning media could support students' learning motivation and mathematical creative thinking skills. These findings are related to student engagement and other learning outcomes but do not directly measure mathematical conceptual understanding. Therefore, the findings of [Nabila et al., \(2025\)](#) are used as supporting evidence regarding the potential of Scratch-based learning activities to encourage students' participation rather than as direct evidence of improvement in conceptual understanding. Similarly, [Putri et al., \(2025\)](#) reported that Joyful Learning could support students' motivation and active participation. Although these outcomes differ from the conceptual understanding measured in the present study, they provide supporting evidence regarding the participatory characteristics of Joyful Learning. In the present study, conceptual

understanding was measured directly through students' performance on the mathematical conceptual understanding test.

The novelty of this study lies in the integration of Joyful Learning, a Scratch-based educational game, and worksheet within a single learning process for social arithmetic. Previous studies have examined Scratch-based media and Joyful Learning from different perspectives, while the present study combines these components as one instructional treatment package. The learning activities connected contextual social arithmetic problems with group interaction, mathematical communication, practice, feedback, and reflection. The findings showed an increase in students' mathematical conceptual understanding across all five indicators after the implementation of the integrated learning process. However, because Joyful Learning and Scratch were implemented simultaneously, their individual contributions to the observed improvement cannot be separated.

Conclusion

Based on the results and discussion, the implementation of Joyful Learning assisted by a Scratch educational game was followed by an increase in students' mathematical conceptual understanding of social arithmetic. The students' mean score increased from 48 on the pretest to 92 on the posttest. The paired-samples t -test showed that the calculated t value was 19.20, which was greater than the critical t value of 1.703 at a significance level of 5%. Therefore, H_0 was rejected and H_a was accepted, indicating a significant difference between students' mathematical conceptual understanding before and after the learning intervention. These findings are limited to the 28 seventh-grade students of SMP Negeri L Sidoharjo who participated in the study and to the social arithmetic topics of profit, profit percentage, loss, and loss percentage. Because Joyful Learning and the Scratch educational game were implemented as a single treatment package, the individual contributions of each component to the observed increase cannot be separated. Therefore, the findings should not be generalized to other grade levels, schools, or mathematical topics without further investigation. Future research is recommended to employ a control or comparison group to provide stronger evidence regarding the effectiveness of the integrated learning approach. Further studies could also involve larger and more diverse samples to increase the generalizability of the findings. In addition, reporting effect sizes is recommended to provide information about the magnitude of the observed change in students' mathematical conceptual understanding.

Conflict of Interest

The author states that there is no conflict of interest related to the implementation of research and writing this article.

Auhor Contributions

M.A. conceptualized the research ideas presented and collected data. The other four authors (L.A.P., and K.U.Z.N.) actively contributed to the development of theory, methodology, organization and analysis of data, discussion of results, and approval of the final version of the work. All authors stated that they had read and approved the final version of this manuscript. The percentage of contributions in the conceptualization, drafting, and revision of this article is as follows: M.A.: 60%, L.A.P.: 20%, and K.U.Z.N.: 20%..

Data Availability Statement

Data supporting the results of this study are available from the corresponding authors upon reasonable request.

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